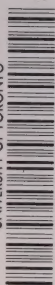




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DEPARTMENT OF PUBLIC HEALTH

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**An Evaluation
of the
Dental Effects
of
Water Fluoridation
City of Toronto
1963 - 1975**

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FOR

THE CITY OF TORONTO
DEPARTMENT OF PUBLIC HEALTH

June, 1976

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PREFACE

The following report was prepared by Dr. D. W. Lewis, Chairman of the Department of Community Dentistry, Faculty of Dentistry, University of Toronto.

On September 4, 1963, Metropolitan Toronto instituted fluoridation of its water supply. The costs per capita for the chemical and labour are estimated at 6.94 cents in 1969 and rose to 10.83 cents for 1975, a consequence of the inflationary process.

Dr. Lewis uses the statistics gathered by the detailed annual dental survey in elementary and secondary schools in the City of Toronto as a basis for this report. The various indices of dental health status are defined and analyzed, possible bias between different examiners is discussed and evaluated and the sampling procedure itself is subjected to close scrutiny.

The status of oral health of various age groups was compared using as a baseline a survey of children conducted in 1963, the year fluoridation was begun. By means of detailed statistical tables and graphs it is shown that in the age groups of 5, 7 and 9 years a reduction of about 50% in decay attack was evident for deciduous teeth once the time for the full effects of fluoridation had elapsed. For permanent teeth decay attack was reduced by about 44% in these age groups. The number of deciduous teeth lost or needing extraction was reduced by over one-half.

The older age groups (11, 13, 15 and 17 years) were almost all born after fluoridation began. Since some of these older children do not have all of their permanent teeth erupted, the final statistical

evaluation for these children is not yet complete. Even so decay attack has been reduced by over one-third as a result of exposure to fluoridated water.

The total number of children of the age groups 5 to 17 years, odd ages only, who were examined in detail for statistical purposes varied each year from 4,189 in 1964 to 3,189 in 1975. This random statistical sample was selected from pupils who were present at school for screening during the dental survey and is representative of the entire school population for which the evaluation was carried out. The number of pupils who were screened fluctuated each year during the period 1964-1975 depending on the enrolment in the City of Toronto schools. For example, 112,901 pupils were screened in 1964 and 91,669 in 1975. Over the 12-year period the numbers screened represented approximately 80-85% of the entire school population.

While the lack of sufficient fluoride leaves tooth enamel susceptible to decay, it is also known that too much ingestion of fluoride may cause an unsightly "mottling" effect of teeth. The report shows that mottling is infrequent and the severe type of mottling is practically non-existent. When mottling does occur, it is the mild type which is not esthetically displeasing.

The study confirms that a water supply fluoridated at the recommended level resulted in improved dental health for the City of Toronto children. This greatly reduces the cost of providing comprehensive dental treatment.

J. McGaughey, D.D.S., D.D.P.H.
Director, Division of Dental Services
June 28, 1976

TABLE OF CONTENTS

	<u>PAGE</u>
Introduction	1
Other Canadian Studies	1
Water Fluoridation in Metropolitan Toronto - Legal and Technical Aspects	2
Study Methods	
1. The Dental Examination	4
2. Indices of Dental Health Status	4
3. Dental Survey Teams and Examiner Differences	5
4. Sampling Procedure and Groups to be Analysed	9
Survey Findings	
1. The Influence of Fluoridation on Deciduous Teeth at Age 5	12
2. The Influence of Fluoridation on Deciduous and Permanent Teeth at Ages 7 and 9	15
3. The Influence of Fluoridation on Permanent Teeth at Ages 11, 13, 15 and 17	21
4. The Influence of Fluoridation on the Tooth Surfaces of the First Molar	25
5. The Influence of Fluoridation on Tooth Mottling	26
Discussion, Summary and Conclusion	29
Bibliography	34
Appendix I	36



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LIST OF TABLES AND FIGURES

<u>TABLES</u>	<u>PAGE</u>
1. Definitions of Indices of Dental Health	6
2. Composition of Dental Survey Teams City of Toronto 1963-1975	8
3. Age 5 Years--City of Toronto Dental Surveys 1963-1975-- Children Born in Metropolitan Toronto	13
4. Ages 7 and 9 Years--City of Toronto Dental Surveys 1963-1975--Children Born in Metropolitan Toronto	17
5. Ages 11, 13, 15 and 17 Years--City of Toronto Dental Surveys 1963-1975--Children Born in Metropolitan Toronto	23
6. Percentage of Children with Tooth Mottling--City of Toronto Dental Surveys 1964-1975	28

FIGURES

1. City of Toronto Dental Survey Card	5
2. Percentage of Children Free of Decay or With Premature Tooth Loss. Deciduous Teeth, Age 5, City of Toronto 1964-1975	14
3. def Deciduous Teeth per Child at Ages 5, 7 and 9. City of Toronto 1964, 1966, 1968, 1970, 1972 and 1974	18
4. DMF Permanent Teeth per Child at Ages 9, 11 and 13. City of Toronto 1964, 1966, 1968, 1970, 1972 and 1974	24

AN EVALUATION OF THE DENTAL EFFECTS OF WATER FLUORIDATION
CITY OF TORONTO 1963-1975

INTRODUCTION

Although the efficacy and safety of water fluoridation is well established from studies throughout the world, no extensive evaluation of the effects after 12 years of water fluoridation in Metropolitan Toronto has previously been done, aside from limited comments in annual health reports of Toronto and the various boroughs composing Metropolitan Toronto. This report describes in detail the dental effects of water fluoridation in the City of Toronto between 1963 and 1975. Water fluoridation is a broad issue which has been studied extensively for a long time. The addition of fluoride to municipal water supplies deficient in them began in 1945 but its presence naturally in water was positively identified in 1931 and speculated about years before then. Those interested in reviewing a variety of aspects (medical and sociological as well as dental) of water fluoridation might wish to consult some of the excellent review publications cited in the bibliography.^{1,2,3,4}

OTHER CANADIAN STUDIES

It is not within the scope of this report to describe in detail other Canadian studies of water fluoridation; however, it may put the present report in perspective to mention some of the Canadian works. Actual details of these are provided in the original articles cited in the bibliography. As might be expected, numerous publications describing the Brantford, Ontario water fluoridation

experience (one of the three original North American water fluoridation studies begun in 1945) have previously been published but no detailed federal studies about Brantford have been done, apparently, in the last 10 years.^{5,6,7,8,9,10} Other Canadian cities, following Brantford's lead, have fluoridated their water supplies and reported publicly upon the results. These include Brandon Manitoba^{11,12}, Wetaskiwin Alberta¹³ and Aylmer¹⁴ and the Borough of North York¹⁵ in Ontario. This latter study demonstrated the savings in dental treatment time and costs resulting from the use of fluoridated water by five year-olds. Other reports exist. Mitchell of the University of Waterloo has published an excellent bibliography concerning the background and behavioural aspects of the fluoridation of community water supplies.¹⁶ This bibliography contains a special section on Canadian studies.

WATER FLUORIDATION IN METROPOLITAN TORONTO-LEGAL AND TECHNICAL ASPECTS

Following eight years of controversy and legal questions, the water supply of Metropolitan Toronto was fluoridated on September 4, 1963. Metropolitan Council first passed a by-law authorizing fluoridation in June 1955. A Supreme Court of Canada ruling in June 1957 forced the rescinding of this by-law in the absence of provincial legislation permitting fluoridation. Applications for the necessary enabling legislation made by Metropolitan Council to the Government of Ontario were rejected in 1958, 1959 and 1960 pending the report of a committee established by the Province to investigate the whole question of fluoridation. Following the tabling of a favourable report by the Morden Committee in January 1961, the Ontario Legislature

approved Bill 98 empowering municipal councils to fluoridate their water systems or submit the question to their electors. The Act stipulated that councils must hold a vote if petitioned to do so by at least 10% of the electors in the municipality or in each of a majority of Area Municipalities in the case of Metropolitan Toronto. In April 1961 Metropolitan Council again passed a by-law authorizing fluoridation, which it was forced to rescind in February 1962 after the anticipated petition for a vote according to the Act was made. The vote in December 1962 favoured fluoridation by a slim margin of 5,964 (177,173 in favour and 171,209 against). In January 1963 By-law 1804 was passed authorizing fluoridation of the Metropolitan Toronto water supply.

Meanwhile, between 1955 and 1963 the staff of the Water Supply Division of the Department of Works of Metropolitan Toronto had time to study carefully the technology of water fluoridation in order to choose the most appropriate fluoride-containing chemical, equipment and sites for fluoridating the water system and to develop an elaborate testing program which would ensure that the proper amount of fluoride was being added to, and distributed in the water. Fluoride (from hydrofluosilicic acid) is added at four points in the water system. In 1975 the average dose of fluoride added to the water was 0.81 part per million (ppm) which, when combined with the 0.14 ppm fluoride already in Lake Ontario's water, gave an average dose of 0.95 ppm--very close to the target of 1.0 ppm.

The estimated cost per person per year for the chemical used in 1969 was 4.58¢ and in 1975 was 7.88¢. Total cost--including the cost of chemicals, labour, power and maintenance but not capital

costs--was estimated at 6.94¢ per person per year in 1969 and 10.83¢ in 1975. The cost of fluoridation, like the cost of dental care, food and housing, has inflated but with fluoridation pennies per person annually are involved.

STUDY METHODS

1. The Dental Examination

Annual detailed and screening dental surveys of the elementary and secondary school students of the City of Toronto have been conducted for about twenty years. Since about 1960 the standard, nationally accepted Canadian Dental Association method of doing dental surveys has been used by the City of Toronto Department of Public Health. Data emanating from these detailed surveys of samples of Toronto's children form the basis of this report. The survey findings for each child are recorded on a combined write-in and mark-sense computer card which subsequently is processed and then analyzed by the section of statistical services of the Department of Public Health using the standard indices of the Canadian Dental Association survey methodology. An example of this card can be seen in Figure 1.

The card contains 25 sections or columns and the examining team receives specific written instruction in a survey procedure manual on how to interpret and complete each of these sections. This is essential to try to achieve standardization among dental examiners. Using the data contained in these columns it subsequently is possible to calculate a number of measures of dental health.

2. Indices of Dental Health Status

To describe dental health status, indices have been developed.

These indices indicate the level of dental disease attack (dental decay, periodontal disease, malocclusion) and the level of dental treatment achieved. Of the 21 indices available the disease attack ones which are used in this report to follow the effects of water fluoridation over time are defined in Table 1.

FIGURE 1: City of Toronto Dental Survey Card

SURNAME		INITIALS										SCHOOL																			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)							
DECIDUOUS		AGE	HEALTH DISTRICT	PLACE OF BIRTH	SPACE MAINTAINER	ORTHODONTIC APPLIANCE	MOLAR RELATION	CUSPID RELATION	CROSS BITE	OVER BITE	OVER JET	CROWDING	DRIFTING	CONGENITAL	STAIN	PLAQUE	GINGIVITIS	DENTAL CARE	LOWER 1ST PERMANENT	MOLARS	PRESCHOOL	WOT-LING									
DECAYED																			EXAM.	B.P.	MES.	B.G.	AGE	EXAM.							
FILLED	0 0			METRO TORONTO	NO	NO	NORM	NORM	NO	NORM	NORM	NO	NO	NO	NO	NO	NORM	NO DEFECTS	C0	C0	C0	C0	C0	C0	NO						
LOST	1 1	3	RIV	ELLENBORO CANADA															C1	C1	C1	C1	C1	C1	1ST MILD						
TO BE LOST	2 2	5	MP	BARRABANT	PLACED	PLACED	MES	MES	ANT	OVER 4MM	OVER 4MM	MAX	YES	YES	YES	YES	CONTOUR ABNORM	COMP CC	C2	C2	C2	C2	C2	C2	2ND MODERATE						
PERMANENT	3 3	7	Y																						3RD SEVERE						
DECAYED	4 4	9	U				DIS	DIS	POST	OPEN	NEG.	MAND					STOPPING ABNORM	PART FC							4TH						
FILLED	5 5	11	P																						5TH						
LOST	6 6	13	H															COLOUR ABNORM	HELECT						6TH						
TO BE LOST	7 7	15	R																												
CODE NOS	8 8	17	E.E.																						9TH						
NAME OF EXAMINER		19																													

CAUTION
MARK THIS CARD ON A HARD SURFACE
DO NOT BEND OR FOLD

AGE	HEALTH DIST.	PLACE OF BIRTH	SPACE MAINT.	ORTHODONTIC	MOLAR REL.	CUSPID REL.	CROSS BITE	OVER BITE	OVER JET	CROWDING	DRIFTING	CONGENITAL	STAIN	PLAQUE	GINGIVITIS	DENTAL CARE	LOWER 1ST PERM.	MOLARS	PRESCHOOL	WOT-LING				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25

DENTAL HEALTH SURVEY CARD

3. Dental Survey Teams and Examiner Differences

The large size of the school population of the City of Toronto requires that a number of qualified dentist- or dental hygienist- recording clerk survey teams, usually 7, be utilized. In addition to individual personnel changes there has been a transition over the past 13 years for dental hygienists to replace dentists in doing these examinations (Table 2). The examining dentists or dental hygienists usually conduct their surveys within the classroom using natural light, single-ended #6 dental explorers and plane mouth

TABLE 1

DEFINITIONS OF INDICES OF DENTAL HEALTH

DECIDUOUS TOOTH MORTALITY	Percentage of children having one or more deciduous tooth or tooth crown lost due to dental caries.
PERMANENT TOOTH MORTALITY	Percentage of children having one or more permanent tooth or tooth crown lost due to dental caries.
DECIDUOUS CARIES FREE	Percentage of children apparently immune to caries on deciduous teeth (i.e. d.e.f. zero).
PERMANENT CARIES FREE	Percentage of children apparently immune to caries on permanent teeth (i.e. D.M.F. zero).
DECIDUOUS AND PERMANENT CARIES FREE	Percentage of children apparently immune to caries on deciduous teeth and permanent teeth.
d.e.f. TEETH PER CHILD	Average number of decayed, prematurely missing, or restored deciduous teeth or tooth crowns per child.
D.M.F. TEETH PER CHILD	Average number of decayed, missing or restored permanent teeth or tooth crowns per child.
TOTAL CARIES AFFECTED TEETH PER CHILD (d.e.f. + D.M.F.)	Average number of decayed, prematurely missing, or restored deciduous and permanent teeth or tooth crowns per child.
PITTED SURFACE RATE	Percentage of erupted and present lower first permanent molars with carious or filled buccal pits.
SMOOTH SURFACE RATE	Percentage of erupted and present lower first permanent molars with carious or filled mesial surfaces.
BUCCAL-GINGIVAL SURFACE RATE	Percentage of erupted and present lower first permanent molars with carious or filled buccal-gingival surfaces.
MOTTLING	Percentage of children with mild, moderate or severe mottling.

mirrors. No radiographs are used so the amount of dental decay recorded is slightly underestimated. However, it is not believed (there is good evidence from dental clinical trials to demonstrate this) that the lack of radiographs markedly influences comparisons of dental health between groups of children surveyed during different years. Thus relative differences in making comparisons are not affected.

Other than the common use of a standardized set of instructions, no actual comparison and calibration of examiners each year is undertaken. Although it is well known that differences among dental examiners occur, it is anticipated that these differences balance out; that is, those who underrecord are balanced by those who overrecord dental disease. This evening-out tendency is enhanced when the number of dental examiners is relatively large, such as in the City of Toronto.

In addition to variations among examiners in any given survey year, variations between examination years due to examiner differences can be anticipated, particularly as the individual examiners changed, to some extent, from year to year in the Toronto surveys (Table 2). In this report comparisons of average measures of dental health based on a combination of all examiners' results are used. While some variations in dental health between individual pairs of examination years may be attributable to examiner differences, it is unlikely that consistent trends in changes in dental health from year to year or between groups of years are a result of examiner differences.

TABLE 2

COMPOSITION OF DENTAL SURVEY TEAMS
CITY OF TORONTO 1963-1975

<u>Year</u>	<u>Dental Examiners</u>
1963	8 dentists
1964	7 dentists
1965	7 dentists
1966	6 dentists
1967	6 dentists, 1 dental hygienist* 3 dentists, 3 dental hygienists**
1968	3 dentists, 3 dental hygienists
1969	4 dentists, 3 dental hygienists* 4 dentists, 2 dental hygienists**
1970	4 dentists, 2 dental hygienists* 4 dentists, 3 dental hygienists**
1971	4 dentists, 3 dental hygienists* 3 dentists, 4 dental hygienists**
1972	3 dentists, 4 dental hygienists
1973	3 dentists, 4 dental hygienists
1974	3 dentists, 4 dental hygienists* 4 dentists, 3 dental hygienists**
1975	4 dentists, 3 dental hygienists* 2 dentists, 3 dental hygienists**

* January to June survey

** September to December survey

In summary then, examiner differences in any given year and among examination years do occur; however, without special studies, it is not possible to assess the magnitude of the influence of such differences. It would be unreasonable, nevertheless, to attribute regularly improving or worsening dental health over the years as being due solely to examiner differences.

Small differences between the examination findings of different years, but not consistent trends, may be attributable to chance differences in sampling even when a random sampling method is used. However if a non-random method is used, the resultant data are non-representative and useless. It is, therefore, important to examine sampling aspects of the City of Toronto school dental surveys.

4. Sampling Procedure and Groups to be Analysed

The method used for the selection of students to get detailed examinations is a random one and is described in the survey manual (p. 13) given each dental team. These instructions follow:

It is essential that those included in the statistical sample for detailed examination and recording onto I.B.M. cards be truly representative of the whole population which one is attempting to describe. For this purpose the sample should be deliberately random, i.e. chosen according to some mechanical system which gives each child the same chance of being selected.

The following sampling procedure is followed in Toronto elementary and secondary schools. Students are inspected in alphabetical order of surname as derived from a classroom list or attendance register. Every 7th child on the list is then tentatively

selected for detailed charting. If a child is absent, the one following the marked name is tried; failing this, the name preceding, and so on. The sampling ratio is carried over from page to page, and from class to class, as if the aggregate of the school constituted a single list. A typical classroom list is shown...

Of the subjects tentatively selected for detailed charting, only those of odd age groups are retained. Subjects of even age groups are rejected. Rapid screening observations for dental notification cards are made from all children in the classroom regardless of whether they form part of the statistical sample or not.

The above sampling procedure should result in a representative sample of approximately one in every fourteen school children. The sample consists of children of the odd ages 5, 7, ..., 19. The numbers of children surveyed over the years are found in Appendix I. It is evident that older children, particularly those 17 and 19 years of age, are not so co-operative in appearing for their dental examinations. The dental health of the 19 year-olds will not be analysed in this report. The 17 year-olds will be, but with the qualification that they may not be truly representative of their age group. Each year two to three thousand children are surveyed by dental hygienists in the preschool clinics in the eight health districts of the City. These preschool children are not truly representative of all children their ages in the City of Toronto since the nature of attendance at these clinics means that this is a self- or, really, parent-selected sample. The preschool dental data, therefore, will not be used in this report.

It might also be observed in Appendix I that the total sample

at each age can be divided into those who stated they were born in Metropolitan Toronto* and those who were born outside of it. This is a useful division when studying water fluoridation since the main point of interest is to observe changes over the years in dental health status of children native to Toronto. It should be noted that birthplace is recorded after dental decay (See Figure 1). It is assumed in this report that children born in Metropolitan Toronto were more-or-less continuously resident here from birth up to the time of the survey. Although there are instances when this would not be true, with the large sample sizes evident at each age the influence of such children on the total sample data is very small.

Those born outside of Metropolitan Toronto (from elsewhere in Canada or outside of Canada) represent a very mixed group in exposure to fluoridation. They may have been negligibly or virtually fully exposed to water-borne fluorides as their teeth developed. Probably their exposure is less, on the average, than the native Toronto group. But since the extent of their use of water fluoridation and the comparability of their initial dental health to other children here or in the communities from which they came are both unknown, children not claiming birth in Metropolitan Toronto will not be analysed here. Information on their dental health status, as well as that of those born in Metropolitan Toronto, may be found in the annual reports of the Division of Dental Services of the City of

* Metropolitan Toronto consists of the City of Toronto and the Boroughs of East York, Etobicoke, North York, Scarborough and York.

Toronto Department of Public Health.

Appropriate measures of the dental health of representative groups of children born in Metropolitan Toronto and having varying exposure to water fluoridation will be compared at each age--5, 7, 9, through to 17 years--to determine whether the time and length of exposure to water fluoridation affects dental health.

SURVEY FINDINGS

For presentation and discussion it is convenient to divide the results of the surveys done between 1963 and 1975 into three major groups according to child age and the type of teeth available in meaningful numbers at that age. These three groups are: (1) age 5--primary (deciduous) teeth only; (2) ages 7 and 9--both primary and permanent teeth; (3) ages 11, 13, 15, 17--permanent teeth only. The indices used to describe the dental health in each of these groups were previously defined in Table 1.

1. The Influence of Fluoridation on Deciduous Teeth at Age 5

The dental health of five year-olds in the City of Toronto from 1963 to 1975 can be seen in Table 3. Since water fluoridation began on September 4, 1963 any child reaching age five on, or after September 4, 1968 (part of the 1968, and all of the 1969 to 1975 groups in Table 3) is presumably fully exposed post-natally (and most of them, pre-natally) to water fluorides. However, it is known that the deciduous teeth of children born up to about 11 months before fluoridation begins are exposed to fluorides since these teeth develop and mature before eruption when the water is fluoridated.¹⁵

TABLE 3

AGE 5 YEARS--CITY OF TORONTO DENTAL SURVEYS 1963-1975--CHILDREN BORN IN METROPOLITAN TORONTO

	<u>1963 *</u>	<u>1964</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>
Deciduous Tooth Mortality (% children)	(25.1)	21.5	20.1	19.7	14.9	12.6	14.4	9.9	9.0	9.0	8.5	7.4	8.0
Deciduous Caries Free (% children)	(26.7)	32.8	32.2	34.8	37.5	42.6	47.5	51.1	54.9	53.8	55.8	58.0	51.8
d.e.f. Teeth (mean (standard deviation)**	(3.87)	3.46	3.29	3.06	2.83	2.41	2.36 (3.17)	1.84 (2.74)	1.62 (2.44)	1.59 (2.39)	1.69 (2.57)	1.47 (2.39)	1.69 (2.56)
Sample Size	(782)	684	771	781	725	796	722	715	667	710	577	578	461

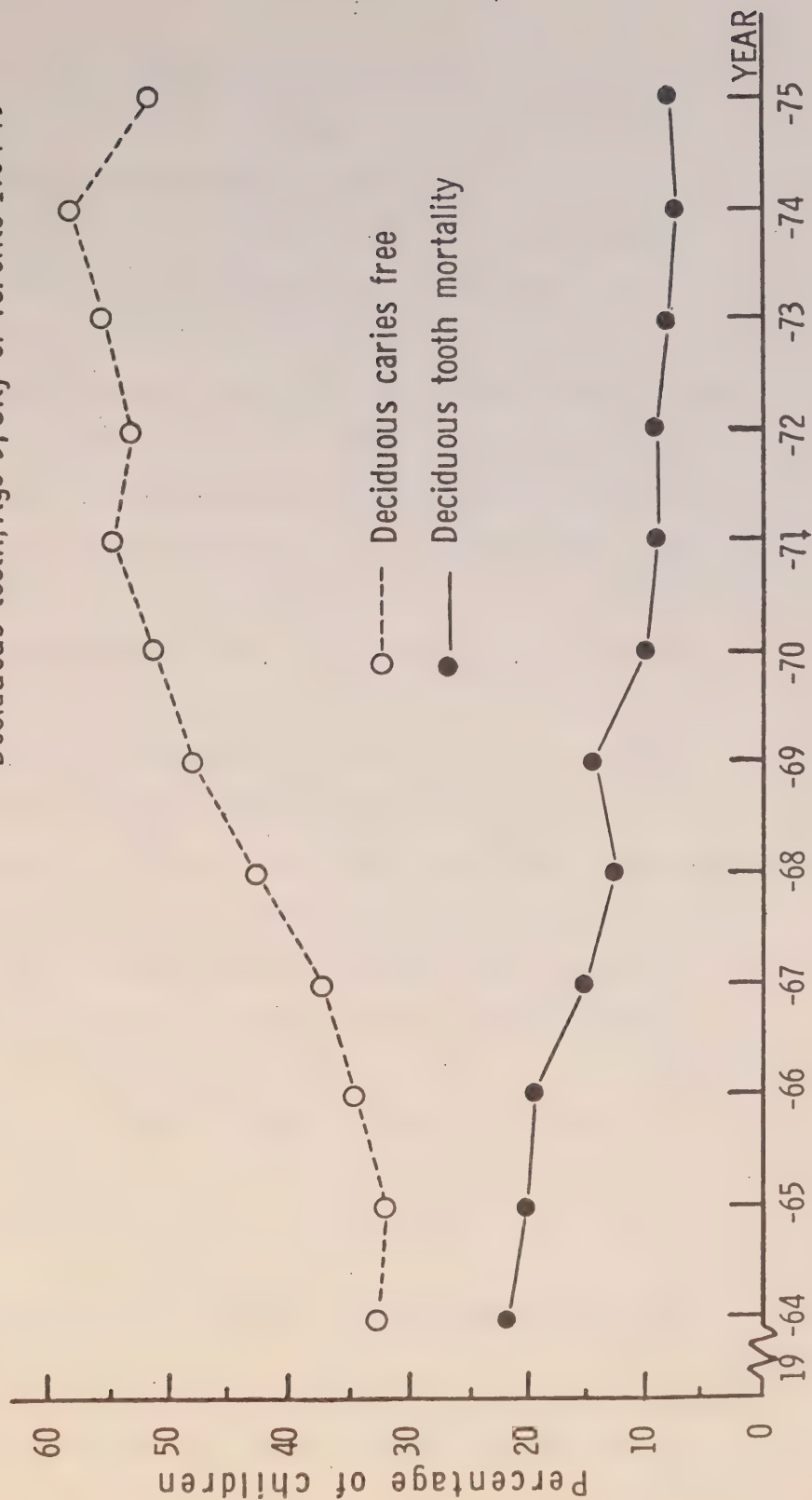
* The 1963 data represent those born in and outside Metropolitan Toronto since birthplace was not categorized in the surveys until 1964.

** It was not possible to compute the standard deviations prior to 1969.

Figure 2

PERCENTAGE OF CHILDREN FREE OF DECAY OR WITH PREMATURE TOOTH LOSS

Deciduous teeth, Age 5, City of Toronto 1964-75



Therefore the teeth of some born in 1962 (the 1967 five year-olds) and those born in 1963 prior to September 4 (part of the 1968 five year-olds) should also demonstrate the effects, if any, of fluorides.

Table 3 and Figure 2 indicate that in 1964 to 1966 about 20 percent of five year-olds had lost at least one deciduous tooth due to decay (Deciduous Tooth Mortality). In 1967 to 1969 when the influence of fluoride began to manifest itself, fewer of these children, about 14 percent, had lost one or more teeth. From 1970 on, when the full pre- and post-natal effects of fluoride should be evident, the percentage is lower still and has seemingly stabilized at about 8% to 9%. Thus the number of children prematurely losing deciduous teeth due to decay has been cut by over one-half from the 1963 to 1966 essentially non-fluoride years.

Concerning children with no deciduous tooth decay (ever) by age five (Deciduous Caries Free), the change is from about one-third of the children free of decay in 1963-1966 to about 45% in 1967-1969 followed by a rise to just over 50% from 1970 on (Table 3, Figure 2).

Similarly the average number of deciduous teeth attacked by decay (d.e.f.) has dropped from about 3.0 to 3.5 teeth in 1964 to 1966 to between 2.4 to 2.8 in 1967-1969 followed by a further decrease to between 1.5 and 1.8 teeth in the period 1970 to 1975 (Table 3, Figure 2). The d.e.f. tooth attack rate has been reduced by 50% from the "before" to "after" water fluoridation periods.

2. The Influence of Fluoridation on Deciduous and Permanent Teeth at Ages 7 and 9

Table 4 indicates that, in addition to the same three deciduous tooth indices considered for children at age 5, three more indices

referring to permanent teeth might be added, for those 7 and 9 years of age. Combinations of deciduous and permanent indices are also utilized since the dental health of the whole child who has both types of teeth in his mouth at these ages is a primary concern.

Children reaching age seven after September 4, 1970 and all of those aged seven years from 1971 to 1975 were born after the start of water fluoridation in Metropolitan Toronto. For the deciduous teeth, children turning seven prior to September 4, in 1970 and in 1969 might also be expected to demonstrate the early, pre-eruptive effects of water fluoridation. For their permanent teeth (the anteriors and first molars) which do not erupt until about six years of age, children seven years of age prior to September 4 in 1970 and in 1968 and 1969 would have had these teeth exposed to fluorides for about one-half of their development. Since uptake of fluoride by teeth in the "maturation" phase after most of their development is completed and prior to eruption is considered to be significant, children reaching age seven in 1967 and the latter part of 1966 may also be influenced by fluorides.

Children reaching nine years of age after September 4, 1972 have been fully exposed to water fluoridation. These children and those reaching nine prior to September 4 in 1972 and in 1971 should demonstrate the effects of fluoride on their deciduous teeth. For permanent teeth, using the same reasoning as with the seven year-olds, children reaching age nine in 1972 prior to September 4 and in 1970 and 1971, and perhaps those in 1968 and 1969, may also demonstrate the effects of fluorides.

TABLE 4

AGES 7 AND 9 YEARS--CITY OF TORONTO DENTAL SURVEYS 1963-1975--CHILDREN BORN IN METROPOLITAN TORONTO

	Age	1963*	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Deciduous Tooth Mortality (% children)	7 9	(48.1) (57.7)	40.4 50.8	46.9 50.2	45.8 52.7	40.8 36.5	39.6 38.7	35.1 49.2	31.7 45.6	22.9 34.5	21.6 33.1	17.1 25.5	16.2 18.9	19.1 18.8
Permanent Tooth Mortality (% children)	7 9	(2.1) (10.0)	1.8 8.4	1.5 9.5	0.9 8.4	1.4 8.4	1.3 5.8	1.0 6.0	0.8 5.8	1.6 4.5	1.0 2.5	0.4 3.9	0.3 1.4	0.0 1.5
Deciduous Caries Free (% children)	7 9	(13.5) (14.2)	15.7 14.3	15.8 13.6	14.4 15.6	16.9 20.1	20.5 20.0	22.8 16.8	26.6 16.9	33.7 22.8	35.3 21.9	38.4 32.5	42.4 36.0	39.1 32.4
Permanent Caries Free (% children)	7 9	(62.7) (28.7)	65.9 29.0	64.6 27.3	71.3 31.4	60.9 27.3	64.8 35.4	67.0 36.0	75.3 42.7	70.6 40.1	69.9 42.7	78.5 44.8	73.3 50.0	78.9 55.8
Deciduous & Permanent Caries Free (% children)	7 9	(12.3) (6.6)	13.6 7.5	14.0 6.9	13.7 8.3	15.3 8.1	17.6 8.9	20.5 9.5	23.4 10.2	28.8 14.2	29.8 13.8	34.7 19.9	36.5 23.5	34.6 23.2
d.e.f. Teeth (mean) (standard deviation)**	7 9	(5.26) (4.83)	4.75 4.80	5.03 4.88	4.85 4.56	4.79 4.19	4.58 4.03	4.18 (3.41) 4.71	3.50 (3.10) 4.18	2.87 (3.06) 3.64	2.73 (2.98) 3.41	2.45 (2.71) 2.67	2.30 (2.73) 2.38	2.46 (2.76) 2.44
D.M.F. Teeth (mean) (standard deviation)	7 9	(0.84) (2.12)	0.77 2.08	0.82 2.13	0.60 1.93	0.94 2.24	0.82 1.86	0.72 (1.24) 1.68	0.50 (1.04) 1.43	0.60 (1.11) 1.52	0.60 (1.10) 1.45	0.44 (1.02) 1.43	0.52 (1.01) 1.20	0.37 (0.83) 1.07
d.e.f. and D.M.F. Teeth (mean).	7 9	(6.09) (6.95)	5.53 6.88	5.85 7.01	5.45 6.49	5.73 6.42	5.40 5.89	4.90 6.39	4.00 5.61	3.47 5.16	3.34 4.86	2.90 4.10	2.81 3.58	2.83 3.50
Sample Size	7 9	(1,072) (1,001)	855 762	917 811	930 848	885 750	951 817	869 767	913 886	864 794	828 759	789 650	666 650	575 547

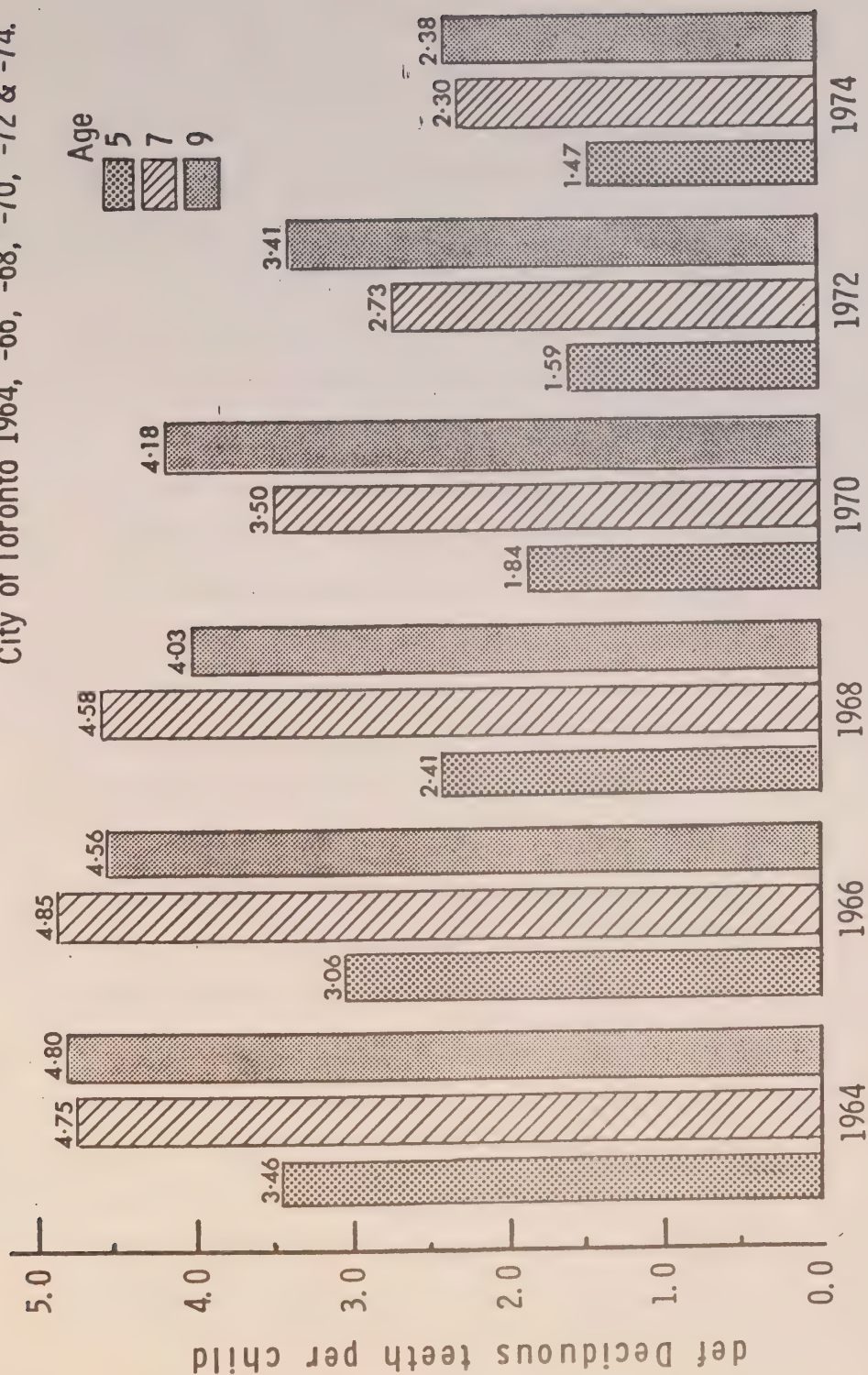
* The 1963 data represent those born in and outside Metropolitan Toronto since birthplace was not categorized in the surveys until 1964.

** It was not possible to compute the standard deviations prior to 1969.

Figure 3

def DECIDUOUS TEETH PER CHILD AT AGES 5, 7 and 9

City of Toronto 1964, -66, -68, -70, -72 & -74.



As seen in Table 4 with both the seven and nine year-olds the percentage of children losing one or more deciduous teeth due to decay decreases as exposure to fluoridation increases. Thus at age seven in the pre-fluoridation period of 1964 to 1968 for deciduous teeth about 40% to 47% of children lose primary teeth prematurely but this drops to about 32% to 35% at early exposure to fluoridation, then drops from 17% to 22% under full exposure. Similar changes occur with the nine year-olds except the initial percentages of around 50% drop first to about 33% then later level off at about 19%. Less than one-half as many children ages seven and nine years lose deciduous teeth prematurely after fluoridation.

For both the seven and nine year-olds from about 14% to 20% of the children are free of decay prior to fluoridation (Table 4). This percentage rises to about 23% to 26% around the time of first exposure to fluoridation for these children and then rises gradually to about 40% for those seven and about 33% for those nine years of age.

As might be anticipated from the above findings the average number of deciduous teeth attacked by decay (d.e.f.) shows the same pattern of improvement for both age groups. Although there are some specific differences between the ages (see Table 4 and Figure 3), the pre-fluoridation averages of from about 4.0 to 5.0 teeth per child are reduced to about 3.5 teeth at the time of first exposure to fluoridation, and then a further large reduction occurs to about 2.4 deciduous teeth attacked per child. Again, as with the five year-olds, the percentage reduction in decay attack is about 50%.

With the permanent teeth of children seven years of age, the tooth mortality, caries free and D.M.F. tooth attack indices all demonstrate improved dental health following fluoridation. However, as can be seen in Table 4, the changes (improvements) in dental health usually begin in 1970 which for these seven year-olds represents children born (mainly) after water fluoridation began. The anticipated first level of improvement in the years 1967 to 1969 is not evident. Even so the reduction in permanent teeth attacked by decay (D.M.F.) is from about 0.8 teeth per child in 1964 to 1968 to about 0.44 teeth per child in 1973 to 1975, a percentage reduction of 45%.

For the permanent teeth of nine year-olds the anticipated two levels of improvement (beginning first with the 1968 group and then lowering again in 1972 and beyond--the "after" fluoridation period) occurs for all three permanent tooth indices (Table 4). For example, the D.M.F. tooth rate is steady at just over 2.0 teeth per child from 1964 to 1967, drops steadily from 1.86 in 1968 to 1.4 in 1972-73, then is further reduced to an average of 1.13 in 1974-75 (also see Figure 4). This change expressed as a percentage reduction from the early to late period is the same as with the seven year-olds, about 44%.

The two combined indices--Deciduous and Permanent Teeth Caries Free and d.e.f. + D.M.F.--further indicate improvements in child dental health with increased exposure to fluoridation (Table 4). This is particularly evident for the nine year-olds free of all decay; only about 8% of these children are completely free of decay

(and fillings) in both dentitions prior to fluoridation while almost three times as many (23%) are free after fluoridation. Similarly the combined d.e.f. plus D.M.F. tooth attack for both ages seven and nine has been almost exactly cut in half after fluoridation's full effects were experienced.

3. The Influence of Fluoridation on Permanent Teeth at Ages 11, 13, 15 and 17

Three indices (Permanent Tooth Mortality, Permanent Teeth Caries Free, D.M.F.) describing the dental health of children eleven to seventeen years of age are found in Table 5. Except for the children reaching age eleven in 1975 and after September 4 in 1974, all these children were born after the start of fluoridation in Metropolitan Toronto. Thus the principal influence of fluoridation to be examined involves post-natal, pre-eruptive effects of varying degrees. The situation with each age group will be discussed in order.

Children reaching age eleven between 1963 and 1968 were mainly over five years of age at the start of fluoridation so their permanent anterior and first molar teeth (the principal teeth available for examination at this age) would be expected to show little effects of fluoridation. Interestingly though, many of these children will have their bicuspid and second molar teeth develop in a fluoride environment but these teeth normally do not erupt until about age twelve. Children reaching eleven between 1970 and 1975 would have their teeth increasingly exposed to fluorides during development with this being particularly true of the 1974-1975 groups who are fully exposed during the tooth developmental and/or maturation periods. Table 5

does indicate with all three indices slight but uneven changes in dental health between 1963 and 1968, after which time improvements, as anticipated, become very noticeable, levelling off in 1973 to 1975--the time of full, or nearly full exposure to the influences of fluoridated water. The D.M.F. tooth index, for example, is seen to drop from between 3.3 to 3.9 teeth in 1963-1968 to between 2.6 and 3.2 in 1969-1972, with a further decrease to about 2.3 teeth in 1973 to 1975 (also see Figure 4). This represents a reduction in decayed teeth of approximately 36% between the average pre- and post-fluoridation eras.

All the children thirteen years of age and older in Table 5 were born after water fluoridation began. With children age thirteen (and older) the bicuspid and second molar teeth will have begun eruption (or erupted) and so be subject to examination along with the permanent anterior and first molar permanent teeth. Since bicuspid and second molar teeth develop later it might be anticipated that water fluoridation will exert an influence on children six to seven years of age and under at the start of fluoridation; that is, children reaching age thirteen from 1970 to 1975 in Table 5. All three indices demonstrate little but apparently random, chance sampling variations until 1970 when perceptible and steady improvements in dental health are evident through to 1975. For example, the D.M.F. tooth index indicates that between 5.1 and 6.0 teeth per child per year are attacked by decay in the period 1963 to 1969. After this period fewer teeth are attacked each year, ending with an average of 3.5 D.M.F. teeth in 1975 (Table 5, Figure 4). This change represents a reduction of about two fewer teeth per child

TABLE 5

AGES 11, 13, 15 AND 17 YEARS--CITY OF TORONTO DENTAL SURVEYS 1963-1975--CHILDREN BORN IN METROPOLITAN TORONTO

	Age	1963*	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975
Permanent Tooth Mortality (% children)	11	(26.8)	24.7	21.9	21.3	19.7	18.9	18.8	15.6	11.0	9.9	7.3	6.6	6.6
	13	(38.0)	33.2	30.3	38.4	31.7	32.7	36.6	27.1	25.0	20.1	16.1	11.3	12.8
	15	(44.8)	42.9	43.1	45.3	44.0	41.0	40.3	42.4	38.4	32.3	30.8	22.2	18.6
	17	(46.0)	45.8	38.6	42.1	40.0	38.5	43.3	38.1	32.0	29.8	23.2	22.6	17.7
Permanent Caries Free (% children)	11	(14.6)	8.2	9.7	14.8	11.5	12.3	16.2	21.6	21.4	22.1	27.0	31.5	26.2
	13	(10.1)	6.0	5.8	4.2	7.0	8.8	5.2	9.3	9.0	10.5	13.8	19.7	17.2
	15	(6.0)	2.5	1.3	3.6	3.2	1.3	3.5	5.1	4.8	3.2	7.4	10.0	9.3
	17	(1.9)	1.2	2.7	2.2	2.4	1.2	1.0	2.2	3.3	2.5	5.6	9.0	13.9
D.M.F. Teeth (mean)	11	(3.59)	3.88	3.69	3.32	3.79	3.53	3.21	2.69	2.56	2.63	2.29	2.23	2.33
(standard deviation)**	13	(5.53)	5.65	5.49	5.91	6.03	5.46	5.11	(2.19)	(2.09)	(2.17)	(2.06)	(2.07)	(2.05)
	15	(7.91)	8.29	8.35	7.81	7.98	8.32	(3.05)	(2.86)	(2.89)	(2.72)	(2.60)	(2.52)	(2.79)
	17	(10.21)	10.59	10.40	9.98	10.07	9.90	(4.37)	(4.07)	(3.68)	(3.41)	(3.44)	(3.47)	(3.60)
								(4.62)	8.70	8.37	8.00	6.93	6.23	4.83
								(4.79)	(4.24)	(4.95)	(3.82)	(3.91)	(3.66)	(3.75)
Sample Size	11	(923)	607	653	668	626	726	672	723	710	709	656	593	545
	13	(838)	491	552	566	499	640	618	656	582	626	607	529	447
	15	(945)	443	471	494	432	379	424	394	419	467	487	441	377
	17	(474)	347	337	321	295	260	208	231	241	275	250	190	237

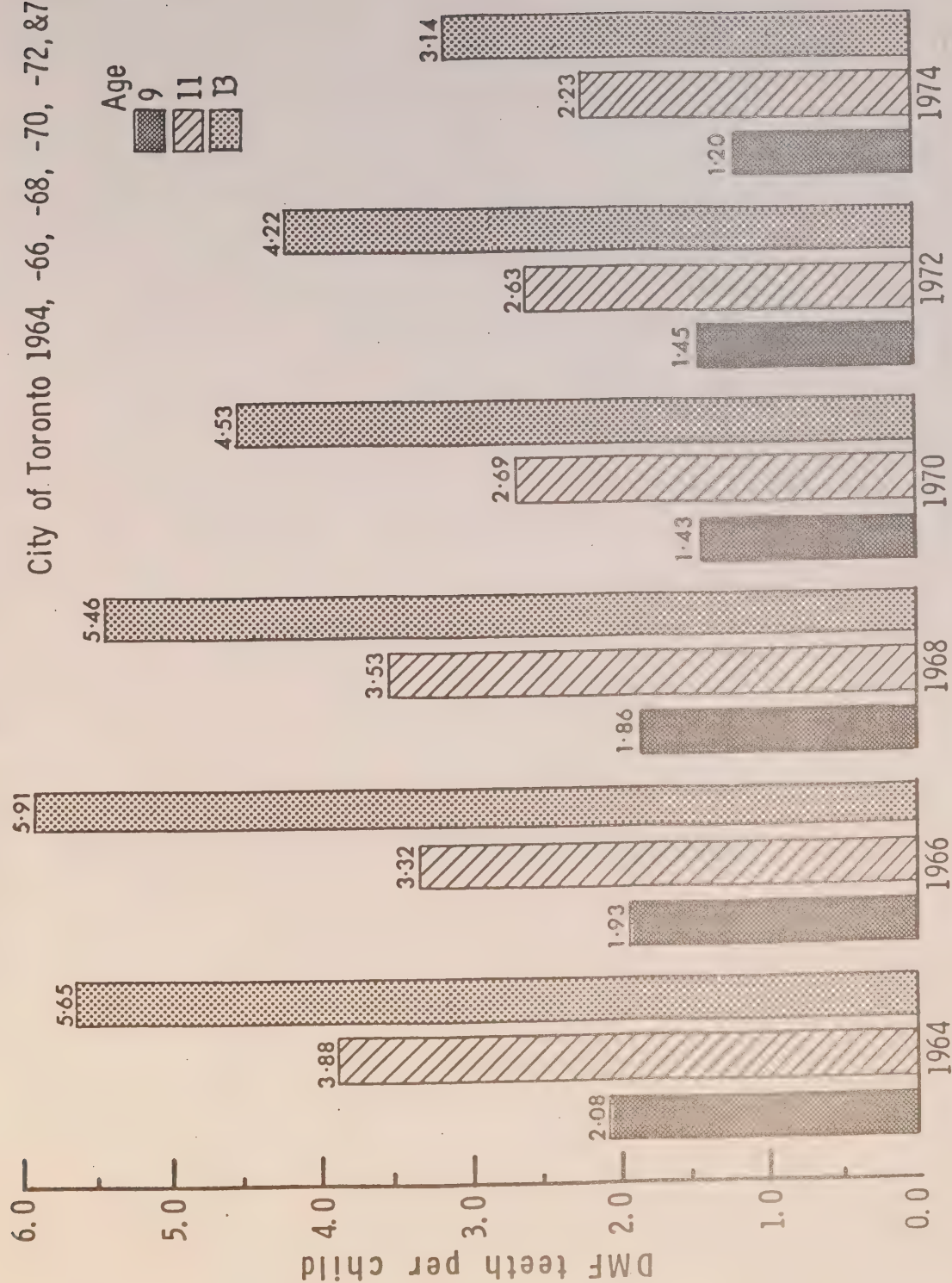
* The 1963 data represent those born in and outside Metropolitan Toronto since birthplace was not categorized in the surveys until 1964.

** It was not possible to compute the standard deviations prior to 1969.

Figure 4

DMF PERMANENT TEETH PER CHILD AT AGES 9, 11 AND 13

City of Toronto 1964, -66, -68, -70, -72, & 74.



attacked by decay, or a percentage reduction of about 35% even though all of these children were born before the start of water fluoridation.

Most of those fifteen and seventeen years of age in Table 5 were six years of age or over when Metropolitan Toronto's water was fluoridated in 1963. Any fluoride influence on tooth development would therefore involve the bicuspid and second molar teeth of children not over about eight years of age when fluoridation began; that is, those reaching fifteen years of age after about 1970 and those reaching seventeen years of age after about 1972. Examination of the data for fifteen year-olds in Table 5 indicates that both the percentage having permanent tooth mortality and the D.M.F. tooth attack rate begin to decline steadily in 1971 and the percentage free of decay rises in 1973. Similarly, improvements in the dental health of seventeen year-olds become evident in all three indices in 1973 although for two of the three, improvements seem to begin three years earlier (in 1970). For both age groups the percentage reduction in D.M.F. teeth is approximately 33%.

4. The Influence of Fluoridation on the Tooth Surfaces of the First Molar

It is well known that the pit and fissure surfaces of teeth decay earlier than their smooth surfaces and that fluorides give greater protection to smooth than fissure surfaces.¹⁷ With this in mind it was of interest to examine the three special recordings made in the City of Toronto dental surveys on the lower permanent first molars of each child (pitted, smooth and buccal-gingival surfaces rates--see Table 1). It was anticipated that increased exposure to water fluoridation would influence decay on the two smooth first

molar surfaces (mesial and buccal-lingual) relatively more than on its pitted surfaces.

At ages seven, nine, eleven and thirteen buccal pit surface decay clearly was more prevalent than smooth surface decay on the same teeth. Buccal pit surface decay decreased slightly as the fluoride exposure of the child increased. At age seven, smooth surface caries was minimal and not apparently related to changing exposure to water fluoridation. At ages nine, eleven and thirteen the mesial smooth surfaces did show relatively greater reduced decay than the pitted surfaces, although this pattern was irregular and not as marked as with some of the indices previously discussed. Backer Dirks¹⁷ had previously found in the Netherlands that smooth buccal surfaces were among the most sensitive surfaces pre- and post-eruptively to the preventive effects of water fluoridation but the very low level and unevenness of attack (1% to 2%) of these surfaces before and after fluoridation in Toronto did not support his findings.

5. The Influence of Fluoridation on Tooth Mottling

The degree of tooth mottling (or dental fluorosis) is recorded for each child in the City of Toronto dental surveys as "not present, mild, moderate, or severe" using adaptations of the standard definitions developed for these conditions by Dean.¹⁸ Since extensive tooth mottling is a sign of excess fluoride ingestion during tooth development and since a low level of mild mottling typically occurs when drinking water is fluoridated, it is important to make these recordings. However the examiner's differential diagnosis between these fluoride-induced tooth markings and other, non-fluoride idiopathic

defects (e.g. white spots) in the surfaces of teeth is very difficult. This is especially true for the milder types of defect involving white flecks or small patches on the teeth, which are usually not even noticed by the patient and are not cosmetically displeasing. Further, it is known that white spots and patches occur in the teeth of about 10% or so of individuals who have never been exposed to fluorides during tooth development and this has previously been reported in Ontario¹⁹ and elsewhere.²⁰ With these diagnostic problems in mind the data for the City of Toronto dental surveys are presented in Table 6.

At each age the percentages of children showing signs of tooth mottling are very low, usually less than 5% and never greater than 11.3%. In spite of the increasing exposure to fluoridation from 1964 to 1975 at each age, especially with the younger children, no particular pattern of increased tooth mottling with increased exposure to fluoridation was evident. Indeed older children born long before fluoridation began display the same low level of mottling as those born after fluoridation. The only pattern which does emerge is that the examiners in 1965, 1971 and 1972 consistently recorded higher levels of mottling for each age than in other survey years (Table 6). This variation underscores the difficulty of making these diagnoses since it is unlikely that such a pattern would otherwise occur. Examiner differences rather than fluorides are clearly one explanation.

Since tooth mottling due to fluoride ingestion is such a controversial issue and since teeth are very sensitive to fluoride excess which eventually shows up as mottling, it was decided to examine

TABLE 6

PERCENTAGE OF CHILDREN WITH TOOTH MOTTLING
CITY OF TORONTO DENTAL SURVEYS 1964-1975

<u>Age</u>	<u>1964</u>	<u>1965</u>	<u>1966</u>	<u>1967</u>	<u>1968</u>	<u>1969</u>	<u>1970</u>	<u>1971</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>
5	1.2	0.9	0.4	0.8	2.8	3.2	3.2	8.7	4.2	0.0	0.5	0.4
7	5.2	6.0	2.7	1.2	3.1	6.0	4.9	9.4	7.0	3.4	2.4	2.4
9	5.1	7.8	3.9	3.2	2.7	3.4	3.4	8.4	9.9	6.0	3.9	1.5
11	5.3	7.2	3.7	1.6	3.2	3.7	2.9	8.3	7.9	3.2	4.2	3.3
13	4.5	6.5	3.2	1.6	2.3	2.1	3.2	4.5	11.3	1.5	1.7	2.7
15	0.9	6.0	2.0	1.6	2.4	2.1	1.3	5.5	4.9	0.8	0.6	0.8
17	0.9	7.1	1.6	3.7	2.7	1.4	0.9	5.0	4.7	0.0	1.1	0.4

mottling more closely in spite of the lack of association just described. Therefore the three categories of tooth mottling (mild, moderate, severe) which are aggregated into one category in the Table 6 percentages, were re-analysed to give the number of children in each category in each survey year from 1969-1975. This revealed several points. The severe type of mottling is very infrequent and when mottling occurs, the mild form is the dominant type. For example during 1972 to 1975, for ages five to thirteen, only three cases of severe mottling in over 12,000 examinations were recorded and in the same time period for age nine children, all of whom were fully exposed to water fluoridation, the breakdown of no, mild, moderate and severe tooth mottling was 2451, 127, 28, and 0 children, respectively.

DISCUSSION, SUMMARY AND CONCLUSION

This report examines data from the City of Toronto school dental surveys between 1963(64) and 1975 in relation to changing (increased) exposure to water fluoridation. Since no suitable control group not using fluoridated water was available the study method of retrospective controls was utilized whereby the dental health of each age group (5 through 17 years) was compared over the available survey period. Thus earlier groups of children at each age acted as controls for later groups of the same ages who were increasingly exposed to water fluoridation. Since so many age groups over so many years were surveyed, a wide range of use of fluoridated water was available--from those seventeen years old at the start of fluoridation to those born seven years after it started.

With this study design, however, it is important to mention the possibility that shifting diagnostic standards by the dental examiners and decreases in dental caries activity over the survey years unrelated to water fluoridation could theoretically account for the observed changes in dental health reported here. It was argued earlier that consistent trends (improvements) with time in dental health are not likely entirely due to examiner differences. Decreased caries activity due to changes in diet, oral hygiene habits and the topical use of fluoride agents (e.g. dentifrices), or in the ethnic composition of the Metropolitan Toronto born sample, may have occurred during 1963 to 1975. It is impossible to quantify the amount and direction of the effects of these factors on dental health status. There is no evidence however that the use by Toronto children of refined carbohydrates (so closely related to decay attack) has decreased. In other non-fluoridated Ontario communities dental survey data do not suggest decreases over the years in dental caries attack. Glass et al. in Massachusetts have demonstrated that there is no evidence for any change in dental decay levels over the past 25 years in low fluoride areas.²¹ These researchers speculated that the increased use of personal preventive measures over the past number of years has been offset by increased caries attack (possibly due to increased use of sugars).

Although the study design does not permit an absolute cause and effect relationship between improved dental health and increased use of fluoridated water to be established, it is clear that dental health did improve consistently with greater exposure to water fluorides and, importantly, at the anticipated times relative to

the stage of development of the susceptible teeth at each age. Therefore, even though these other factors may have influenced dental health for better or worse, the influence of fluoridated water on the teeth of City of Toronto continuously resident children as documented in this report is inescapable.

A brief summary of this report's findings will now be presented.

Three indices of dental health status for each of the deciduous and permanent dentitions alone and in combination were used to measure dental health status. For each age all indices show that there was a gradual improvement in dental health with increased use of fluoridated water. For the younger age groups there was a general levelling off at a new, improved dental health status when the full effects of fluoridation were realized. It was further observed that these improvements in teeth corresponded with the times of first exposure of these developing teeth to fluoridated water.

Children five, seven and nine years of age had better teeth at each age after water fluoridation than children of similar ages before fluoridation's influence. After the full effects of fluoridation the number of children who had lost or needed extraction of, deciduous teeth was decreased by over one-half. And two to three times as many children had experienced no decay at all in these teeth. The number of their teeth attacked by decay was reduced by about 50% for deciduous teeth (d.e.f.) and 44% for permanent teeth (D.M.F.); this represents an average of about 1.5 (age 5)

to 2.1 (ages 7 & 9) fewer deciduous teeth and about 1.0 permanent tooth (age 9) attacked per child.* This is a substantial saving both in terms of teeth and potential dental bills.

For the older Toronto children (ages 11, 13, 15 & 17), who nearly all were born after fluoridation began, dental health also has improved. Differences at each age were observed between permanent teeth which had developed and erupted before fluoridation and teeth increasingly developing after the water was fluoridated. There were between 33% and 36% reductions in the D.M.F. tooth attack rates even though many of the teeth (first molars and anteriors) used as the "after" fluoridation data in these calculations had only been marginally exposed to water fluoridation as they developed. These percentage reductions represent savings of from about 1.5 to 3.5 permanent teeth per child in each age group.*

Regarding the special recordings of surface decay on the lower permanent first molars, it was found that smooth surface (mesial) decay was reduced relatively more than pitted surface decay. This supports the findings of others that fluorides preferentially protect smooth surfaces relatively more; however the differences in Toronto were somewhat irregular and not so clear-cut.

Tooth mottling whether fluoride-induced or due to other unknown causes, was low in prevalence (averaging less than 5%) and,

* These savings in teeth represent differences in accumulated decay between "before" and "after" fluoridation tooth attack averages at each age. Savings in annual increments of decay would be of the same order of percentage reduction but smaller in terms of teeth since annual attack of course is much lower than accumulated attack up to any given age. Annual incremental data involves examination of one group of children each year for a number of years.

when it occurred was of the mild category which is not considered cosmetically displeasing.

The fluoridation of Metropolitan Toronto's water supply in 1963 has resulted in improved dental health of the City of Toronto children. These improvements are similar in amount and kind to those reported by other North American communities.

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APPENDIX I

SAMPLE SIZE IN CITY OF TORONTO DENTAL SURVEYS

BY YEAR OF SURVEY, AGE AND BIRTHPLACE

Year	Age	Total Number Born in Metropolitan Toronto			Year	Age	Total Number Born in Metropolitan Toronto			Year	Age	Total Number Born in Metropolitan Toronto		
		Total Number Surveyed	Total Number Surveyed	Total Number Surveyed			Total Number Surveyed	Total Number Surveyed	Total Number Surveyed			Total Number Surveyed	Total Number Surveyed	Total Number Surveyed
1964	5	866	684	917	1965	5	771	904	781	1966	5	904	781	725
	7	1,138	855	1,186		7	917	1,198	930		7	1,198	930	885
	9	1,066	782	1,129		9	811	1,156	848		9	1,006	750	750
	11	954	607	1,041		11	653	1,082	668		11	960	626	626
	13	882	491	940		13	552	959	566		13	792	499	499
	15	816	443	842		15	471	954	494		15	754	432	432
1968	17	619	347	562	1969	17	337	614	321	1970	17	515	295	295
	19	128	60	147		19	85	192	88		19	192	107	107
	5	928	796	822		5	722	851	715		5	803	667	667
	7	1,228	951	1,105		7	869	1,219	913		7	1,164	864	864
1972	9	1,164	817	1,040	1973	9	767	1,223	886	1974	9	1,094	794	794
	11	1,113	726	991		11	672	1,126	723		11	1,070	710	710
	13	1,033	640	1,037		13	618	1,037	656		13	896	582	582
	15	646	379	726		15	424	647	394		15	724	419	419
	17	445	260	422		17	208	406	231		17	445	241	241
	19	89	35	107		19	48	101	48		19	104	40	40
1976	5	830	710	720	1977	5	577	684	578	1978	5	591	461	461
	7	1,139	828	1,060		7	789	927	666		7	793	575	575
	9	1,080	759	975		9	650	934	650		9	765	547	547
	11	1,027	709	985		11	566	915	593		11	788	545	545
	13	973	626	938		13	607	810	529		13	665	447	447
	15	779	467	794		15	487	638	441		15	555	377	377
1980	17	446	275	460	1981	17	250	310	190	1982	17	330	237	237
	19	76	33	95		19	39	47	27		19	46	30	30

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